Life in the Cosmos

Richard B. Hoover
NASA/VP-62
George C. Marshall Space Flight Center
Huntsville, AL 35805

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Life in the Cosmos Panel
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Life in the Cosmos

All Known Life Forms Require: *WATER, BIOGENIC ELEMENTS* (C, H, O, N, P, S)

Minor Elements: (Na, K, Cl, Mg, Mn, Fe, Ca, Cu, Zn)

Nitrogen Required in all DNA, RNA, Proteins & Enzymes

& ENERGY

Photoautotrophs – Energy from Light

Organotrophs – Eat Organics (Sugars, Proteins, etc.)

Chemotrophs – Energy from Chemicals

Lithotrophs – Energy from Abiotic Elements/Rocks

Aerobes – Respire using Oxygen as Electron Acceptor

Anaerobes – Use Other Acceptors (NO_3, SO_4^{2-} or S)

Life in the Cosmos

Recent Discoveries Challenge the Long Held Paradigm that Liquid Water (and Life) Can Not Exist on Present-Day Mars and Comets

- **Microbial Extremophiles Live in Glaciers and Grow at Sub-Zero Temperatures**

- **MRO & StarDust Data Show Liquid Water Exists Episodically on Mars and in Comets**

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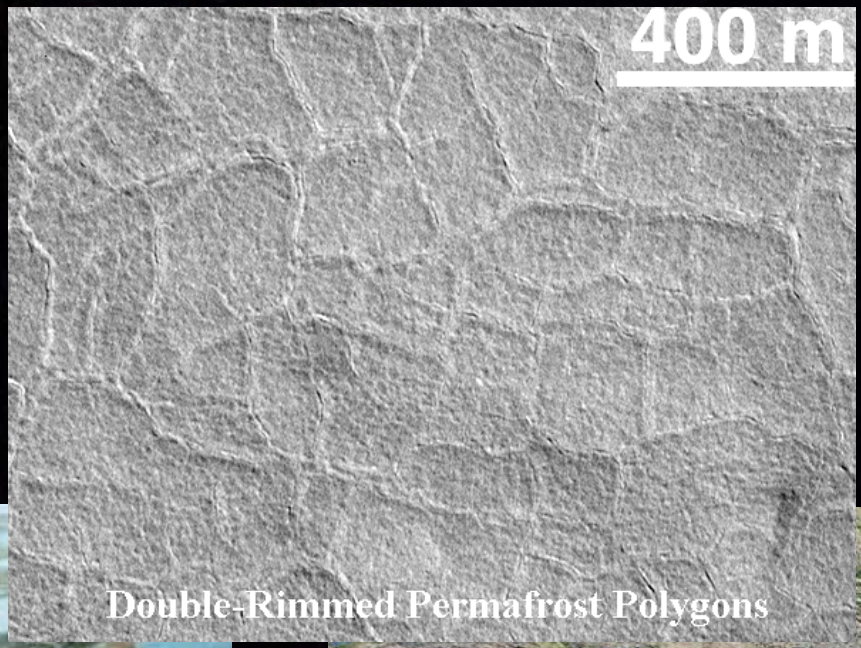
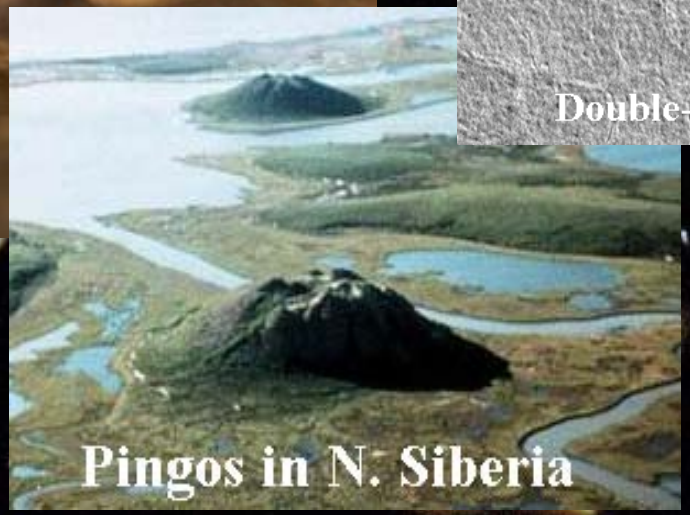
Evidence for Recent Water on Mars

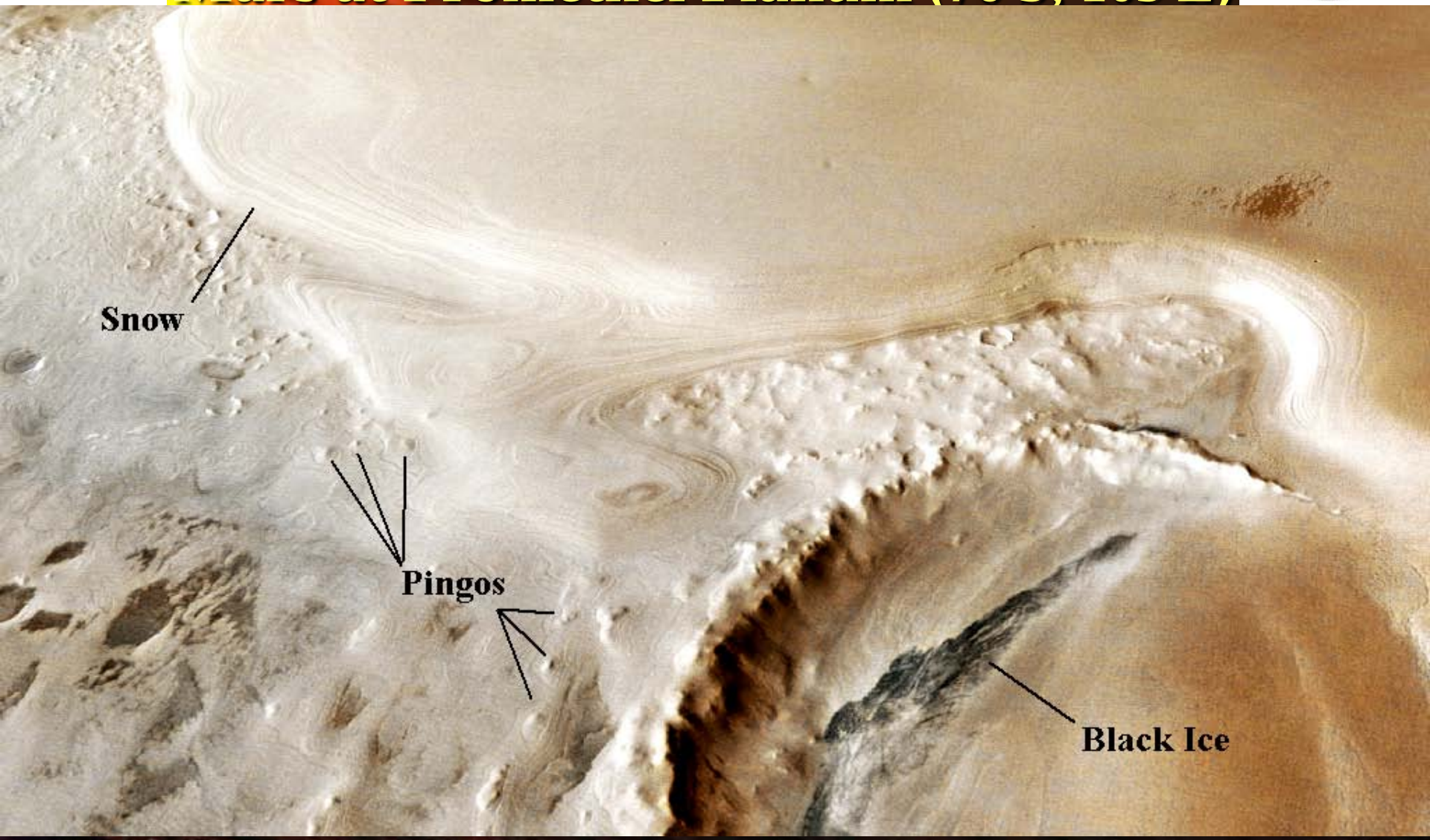
Mars Global Suveyor





Pingos and Double-Rimmed Polygons form only by Freeze-Thaw Cycles in Permafrost. N. Polar Cap of (Mars (1,200 km dia. X 3 km) Water Ice with Pingos & Polygons

ESA/HRSC Image of Snow & Pingos on Mars at Promethei Planum (76 S; 105 E)



Sept. 22, 2005-HRSC on ESA Mars Express Spacecraft Discovers 3,500 M thick layer of Water Ice & Snow with Pingos at Promethei Planum

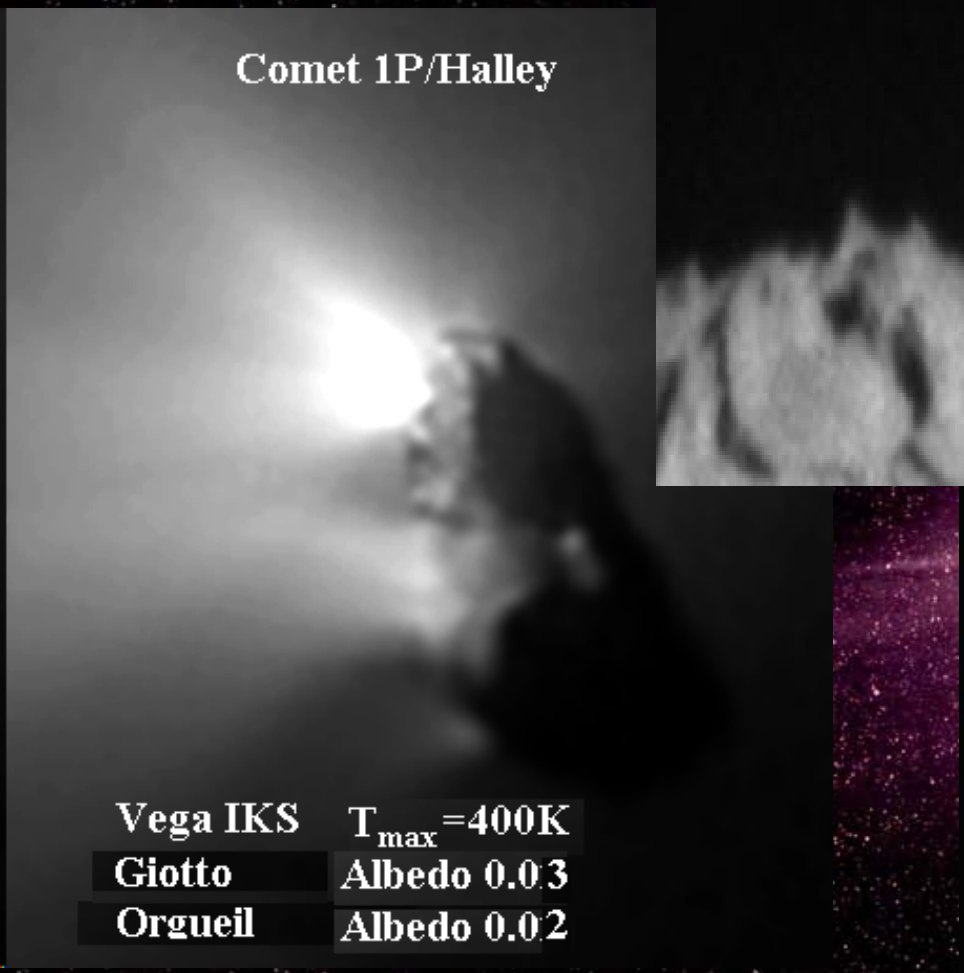
Life in the Cosmos

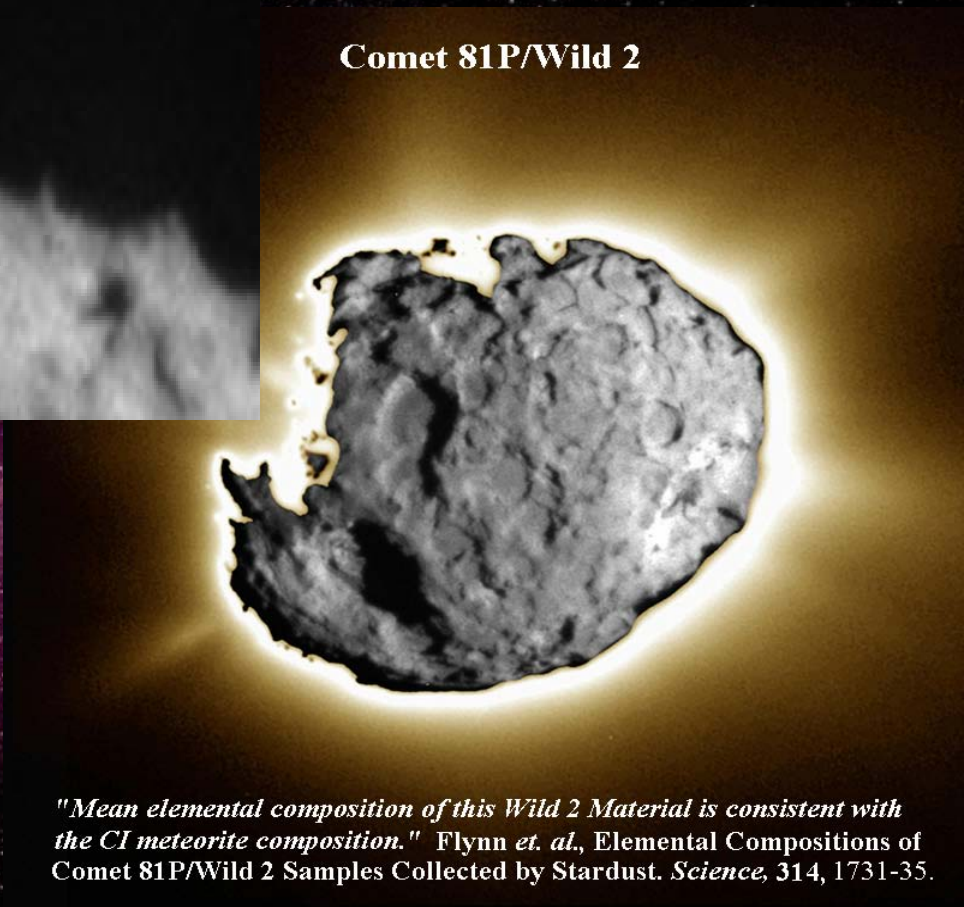
Evidence for Recent Water on Mars

Seasonal Flows on Warm Martian Slopes
Alfred S. McEwen, *et al.*, *Science* **333**, 740 (2011)

MRO HiRISE Images of Recurring Slope Lineae

Hot, Black, Wet, Comet Nuclei ~ CI1 Carbonaceous Meteorites





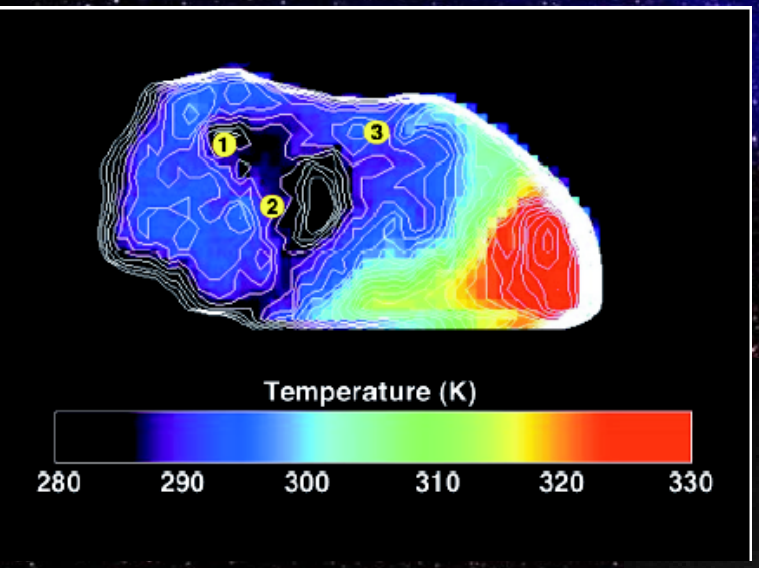
Galileo Image of Comet Halley Nucleus (Albedo 0.03 ~ Orgueil 0.02)

Stardust Images Pinnacles, Cliffs & Jets of Comet 81P/Wild 2

Water Ice on Comet Nucleus

Sunshine *et al.* *Exposed Water Ice Deposits on the Surface of Comet 9P/Tempel 1 Science 311, 1453, 2006*

Comet 9P/Temple 1

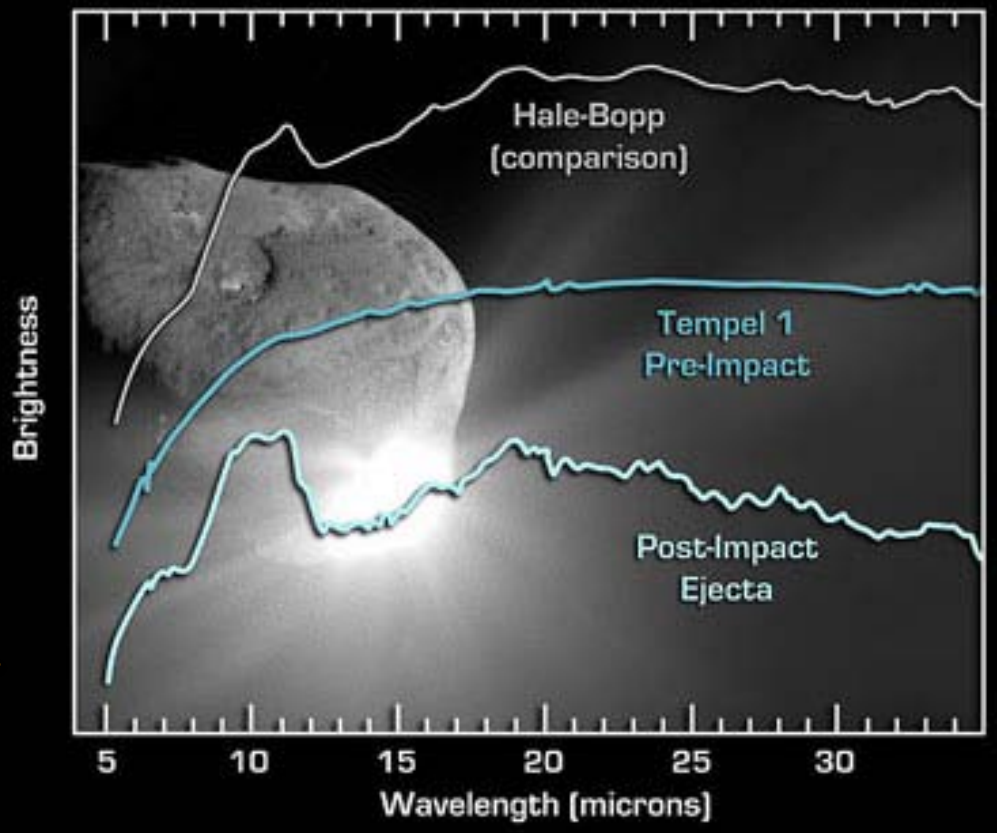


Deep Impact Images of Water Ice on Nucleus of Comet 9P/Temple 1

Spitzer IRS Data on Temple 1

Spitzer IRS **Post-Impact data show at least 50% of Comet 9P/Temple 1 is Water Ice. Also detected were H-CN, Methanol, CO, CO_2, PAHs, Clays and Carbonates.**

Rotation Period ~41 Hrs. changes with Jets and Comet Activity.



Feb. 14, 2011 Stardust NExT Images of Comet 9P/Temple 1

NASA/JPL-Caltech Cornell

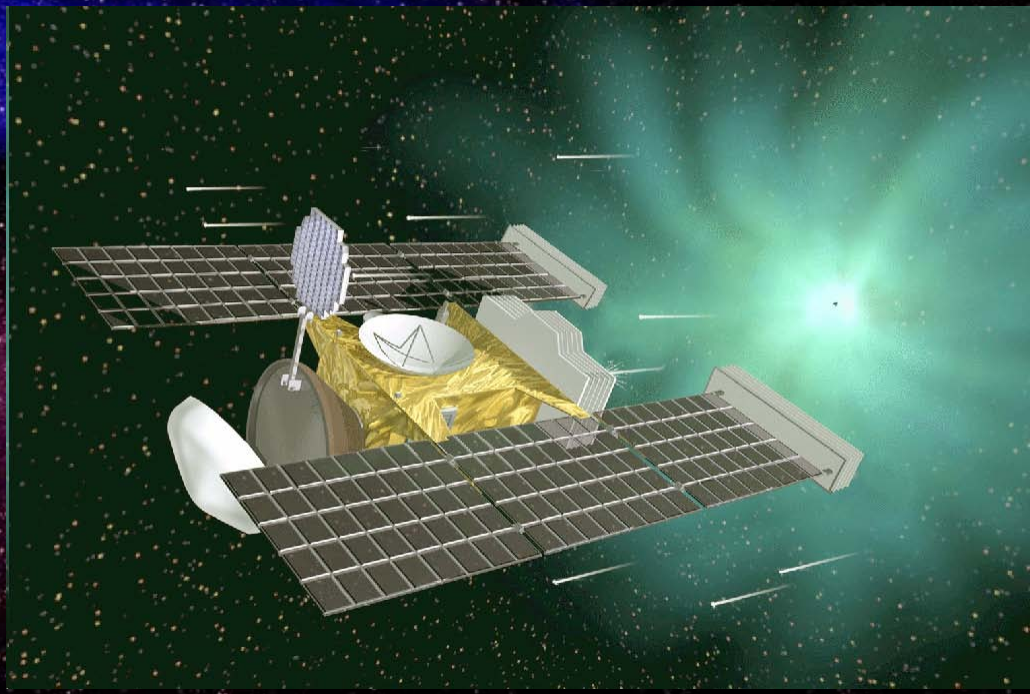
***Stardust NExT* Images of Comet 9P/Temple 1 8:39 p.m. PST**

Extraterrestrial Glycine, Cubanite & Water in Orgueil and Comet 81P/Wild 2

Extraterrestrial Glycine & Cubanite Found in Stardust Samples returned from Comet 81P/Wild 2

$\delta^{13}C = +29\ ^{+}/_{-}\ 6^{o}/_{oo}$

Elsila, J. E., Glavin, D. P., and Dworkin, J. P. "Cometary Glycine detected in samples returned by Stardust. *Meteoritics and Planetary Science*, **44,** 1323-1330 (2010).

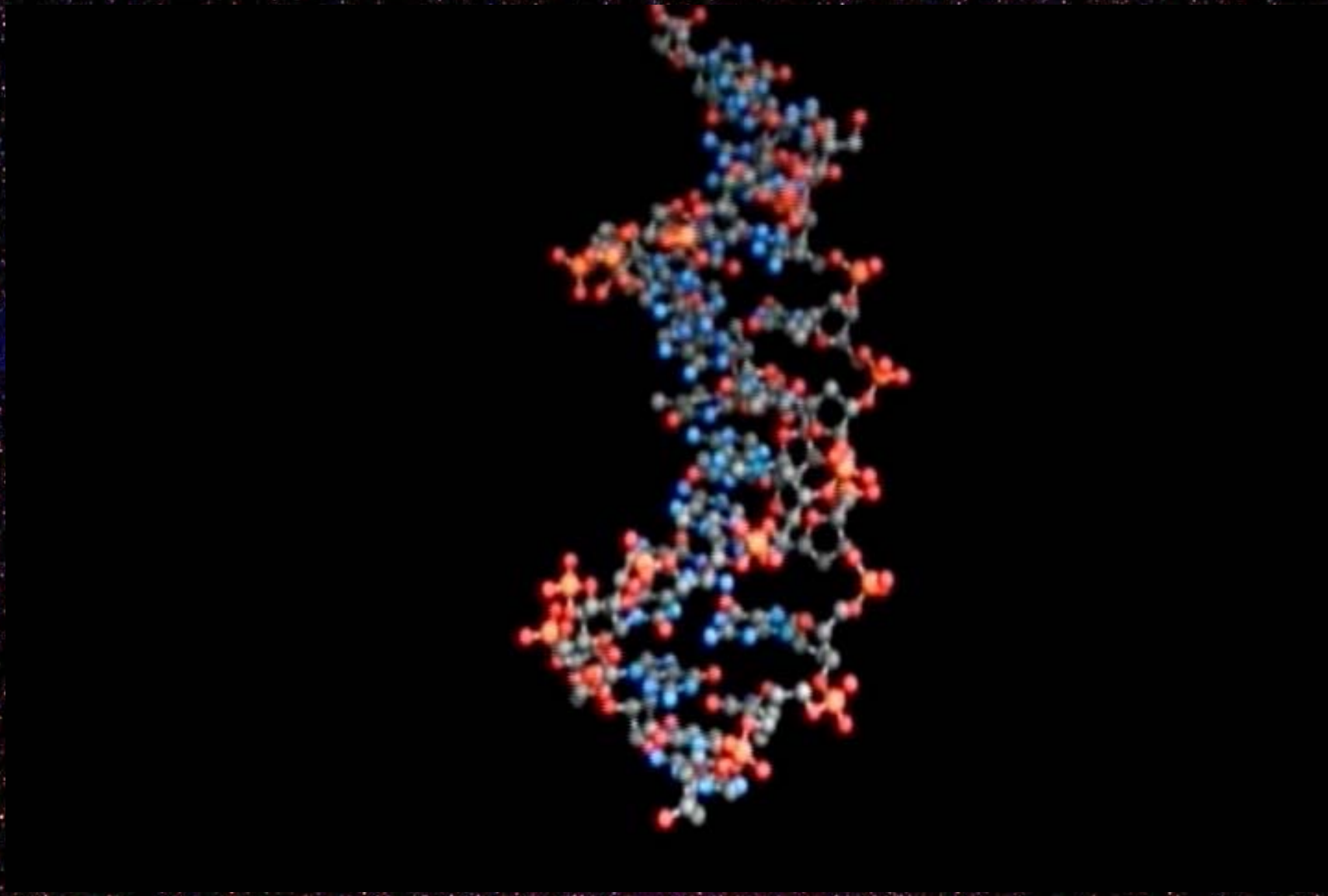


Hydrothermal synthesis of cubanite under conditions relevant to the CI-chondrite parent body

E. L. BERGER*[1], D. S. LAURETTA[1] AND L. P. KELLER[2]

Orthorombic Cubanite ($CuFe_2S_3$) found in Comet Wild 2 & Orgueil CI1 Meteorite forms in Liquid Water at Temperature 20 – 150 ^{o}C; pH 7-10

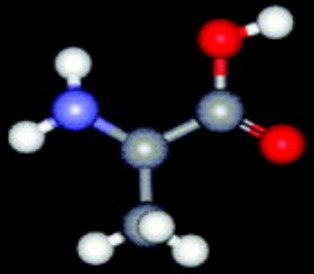
Nitrogen in Biology



Nitrogen in DNA and Iron Hydrogenase

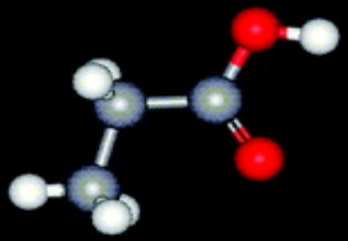
Chiral Biomarkers in Murchison Meteorite

- hydrogen
- carbon
- nitrogen
- oxygen
- sulphur



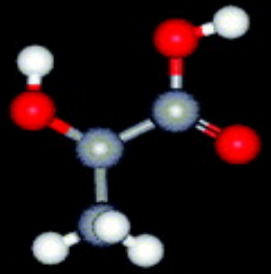
L-Alanine, L-Glutamic Acid, L-Aspartic Acid, GLY, AIB, IVA

amino acids



Proprionic acid - Metabolism of Sugars and Fatty Acids by Proprionyl Coenzyme-A

carboxylic acids

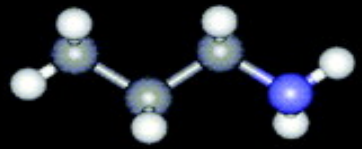


Lactic acid-Pyruvate Oxid. Stecker-Cyanohydrin Synth.

hydroxyacids

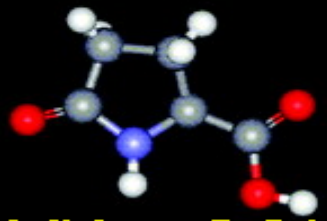
Polyols and Dihydroxyacetone DNA; RNA; Membranes; Energy

sugar-related compounds



17.8% L-Enantiomeric Excess of sec-butyl amine

amines

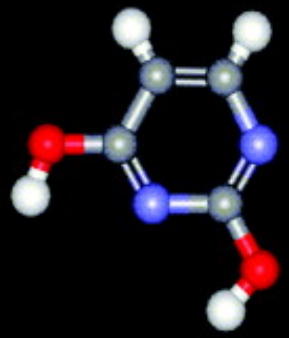


Amide linkage - Defining Molecular Feature of Proteins

amides

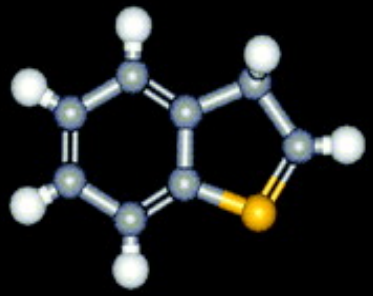
Sephton, Mark A. "Organic Matter in Carbonaceous Meteorites: Past Present & Future Research." *Phil. Trans. Roy. Soc. A,* 363, 2229-2742, (2005)

MISSING: Cytosine and Thymine
Cytosine =>Uracil 17,000 yr. Half Life



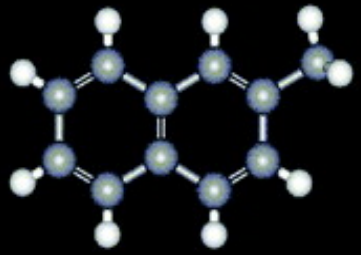
PURINES: Adenine, Guanine, Xanthine, Hypoxanthine
PYRIMIDINE: Uracil

nitrogen heterocycles



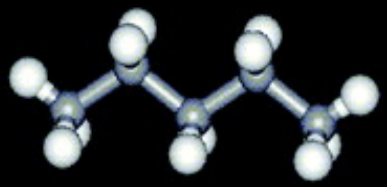
Benzothiophene, Dibenzothiophene Found in Lignite Tar

sulphur heterocycles



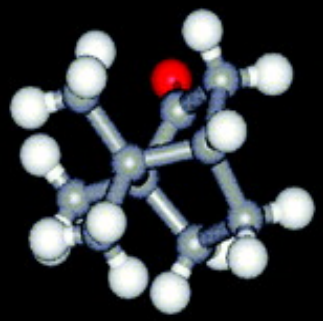
Over 30 Polynuclear Aromatic Hydrocarbons -- Kerogens

aromatic hydrocarbons



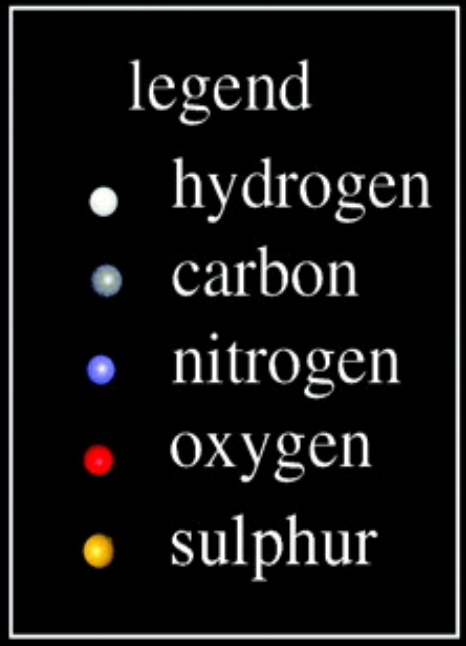
Cycloalkanes and Diverse Suite of C15-C30 Branched Mono, Di-and Tri-Cyclic Alkanes

aliphatic hydrocarbons



Polymers of Isoprenes (C5H8)n Major Buiding Blocks of All Life

terpenes



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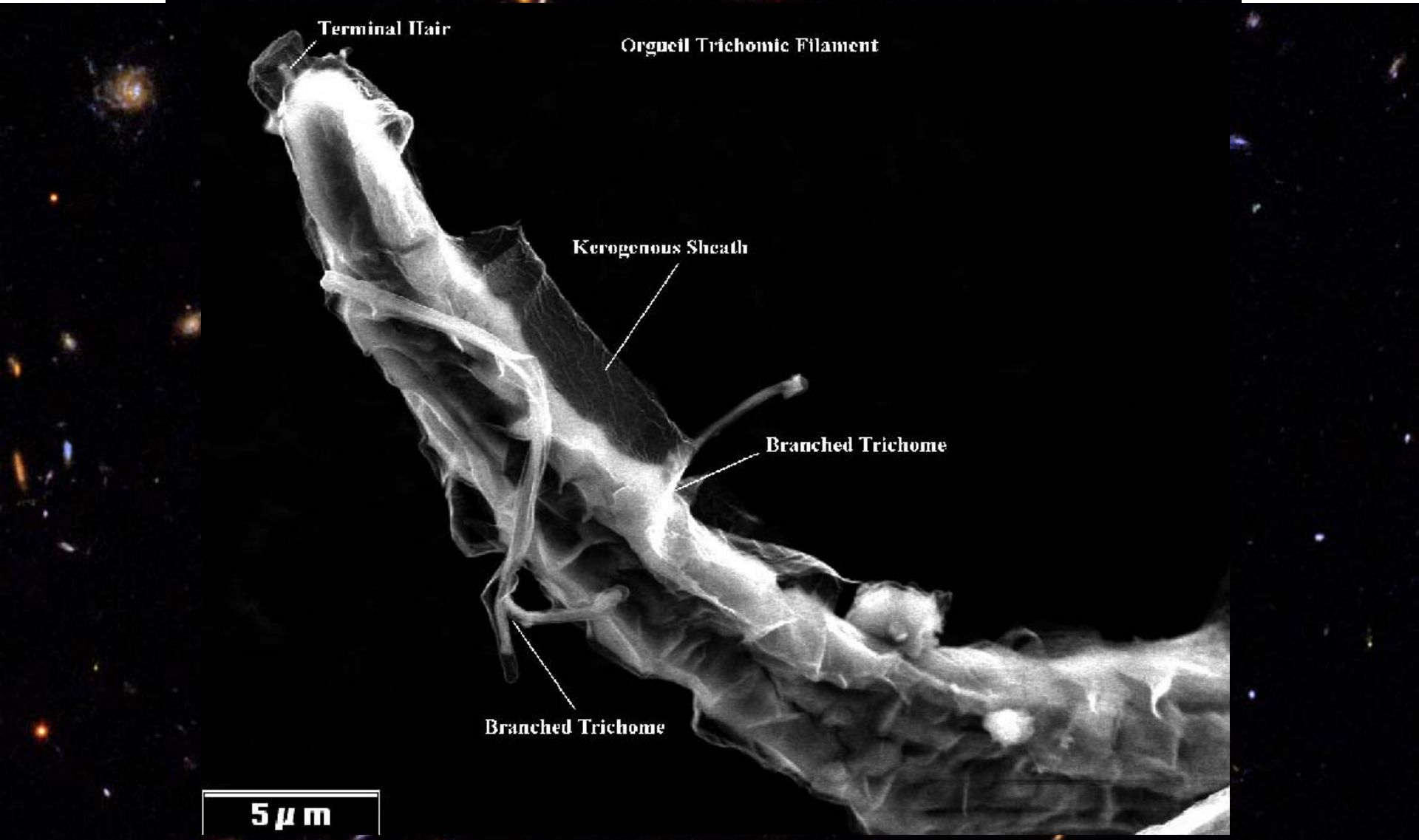

Orgueil Trichomic Filament: O/C<0.1; N<0.5

Life in the Cosmos

Conclusions

Discoveries by NASA & ESA Spacecraft provide additional evidence for present day liquid water on Mars and water/ice jets on Comets & Enceladus.

Stardust mineralogical data support the Hypothesis that water-rich Comets represent parent bodies for the CI1 Carbonaceous Meteorites.

Undetectable Nitrogen & low O/C ratios in Filaments found in CI1 Orgueil meteorite rule out Modern Biological Contamination Hypothesis.